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CHARACTERIZATION OF COLOR IMAGING SYSTEMS

Field of the Invention

The present invention relates to color imaging systems. More particularly, the present invention relates to characterizing color imaging systems to account for perceptual effects.

Background of the Invention

Color reproduction processes typically involve using color imaging systems to produce colors on various media. These color imaging systems may be used to duplicate a color image from one medium to another medium, *e.g.*, from one printed copy to another or from a display screen to a printed copy. Color reproduction processes are used in various application environments, for example, color proofing applications. In color reproduction processes, rendering colors similarly across different media is desirable. To reproduce colors accurately, many processes use color coordinate systems known as color spaces to characterize the color output of color imaging systems. One

commonly-used color space is Commission Internationale de l'Éclairage (CIE) $L^*a^*b^*$ space.

Color spaces can also be used to characterize the color output of one color imaging system relative to other color imaging systems. Characterizing a color imaging system typically involves calculating a color response function for the color imaging system using the coordinates of the color space, *e.g.*, the L^*, a^*, and b^* coordinates of the CIE $L^*a^*b^*$ space.

Color characterization systems often attempt to account for psychophysical and other effects on human color perception. If inadequately addressed, these effects potentially introduce non-uniformities in color characterization across color imaging systems. These non-uniformities may result in differences in color appearance between different color imaging systems and decrease the accuracy of color characterization.

One psychophysical effect on human color perception, known as adaptation, involves the effect of surrounding colors on the subjective appearance of a color. For example, colors appear darker when viewed against

relatively light backgrounds. Conversely, dark backgrounds cause colors to appear lighter than they actually are.

Many color imaging systems are used in connection with displaying colors against a nominally white background or white reference, such as paper or other media. Different color imaging systems may involve producing colors on media having different white references. The human eye perceives the different white references as white and other colors produced on the media relative to the respective white references. As a result, a single objective color is subjectively perceived differently against different backgrounds.

Some color characterization systems attempt to compensate for differences in white references by using transformations to modify tristimulus values based on the white reference. While such systems are effective in characterizing relative color within a single color imaging system, given a particular imaging medium and a particular set of viewing conditions such as illumination and viewing angle, many of these systems produce less accurate results when transforming colors between different color imaging systems. One problem inadequately considered by many color

characterization systems is the effect of variations in white reference for different color imaging systems due to differences in the imaging substrate or display white point. For example, some color characterization systems that use the CIE $L^*a^*b^*$ color space produce non-uniformities in matching color proofing systems having different imaging substrate white reference. In particular, some such color characterization systems have been observed to produce severe non-uniformities when mapping from a substantially white imaging base to a somewhat blue-shifted imaging base.

Other color characterization systems using different color spaces have been observed to produce uniform mapping in light shades of colors, but less uniform mapping in more intense colors. As a result, after a transformation function has been generated to match color values between two color imaging systems, a human operator typically engages in significant empirical adjustment to obtain an acceptable visual match. This empirical adjustment is potentially labor-intensive and time-consuming.

Another psychophysical perceptual effect is known as black point adaptation. This phenomenon involves the perception of a near-black color as black despite the

presence of stray light that imparts non-zero tristimulus values to the near-black color. This effect is particularly noticeable when a color characterization system attempts to characterize perceived colors on a computer monitor, where near-black colors appear black despite significant stray light that devices measure as having tristimulus values significantly higher than zero.

Other color imaging systems are also susceptible to perceptual effects attributable to black point adaptation. For example, using certain color characterization systems to simulate newspaper colors on opaque paper results in reproduced colors that appear washed out. This result is attributable to the significant non-zero tristimulus values for the darkest color or black reference formed on newsprint. These non-zero tristimulus values are partially attributable to stray light scattered from the coarse fibers and partially attributable to inadequate ink coverage of the newsprint. Many conventional color characterization systems fail to adequately compensate for black point adaptation.

Summary of the Invention

According to one embodiment, the present invention is directed to a method for characterizing a color imaging system. The method includes obtaining first color values in a color coordinate system using output samples of the color imaging system. The first color values represent the colors of the output samples and are converted into second color values in a device-independent color coordinate system using first reference values, *e.g.*, a white reference vector, and second reference values, *e.g.*, a black reference vector. The first reference values are adjusted using the first color values. Another embodiments are directed to an arrangement and a data storage medium for performing this method.

According to another embodiment of the present invention, a color characterization method includes obtaining first color values in a color coordinate system. The first color values represent colors of output samples of the color imaging system and are converted into second color values in a device-independent color coordinate system. First and second reference values are used in the conversion process. The first reference values are calculated using

the second reference values, which are calculated as a function of a medium. The first reference values are adjusted using the first color values.

According to a system embodiment of the present invention, color characterization is effected using a computer arrangement. The computer arrangement is configured and arranged to receive first color values in a color coordinate system. The first color values represent colors of output samples. A memory is responsive to the computer arrangement and is configured and arranged to store second color values in a device-independent color coordinate system. The computer arrangement is further configured and arranged to convert the first color values into the second color values using first and second reference values, the first reference values being adjusted using the second reference values.

Another aspect of the present invention is directed to a color transformation method for performing a color transformation between first and second color imaging systems. The color transformation method includes obtaining first and color values respectively representing colors of output samples of the first and second color imaging

systems. The first and second color values are respectively converted into third and fourth color values using a device-independent color coordinate system. First reference values are calculated from a medium, and second reference values are calculated from the first reference values. The second reference values are adjusted using the first and second color values. Color transformation values are generated using the third and fourth color values. The method may be performed by a color transformation arrangement.

The above summary of the invention is not intended to describe each disclosed embodiment of the present invention. This is the purpose of the figures and of the detailed description that follows.

Brief Description of the Drawings

Other aspects and advantages of the present invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 is a block diagram illustrating a color characterization arrangement, according to one embodiment of the present invention;

FIG. 2 is a flow chart illustrating an example color characterization method, according to one embodiment of the present invention; and

FIG. 3 is a flow chart illustrating a color transformation method, according to another embodiment of the present invention.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

Detailed Description of the Various Embodiments

The present invention is believed to be applicable to a variety of systems that characterize color imaging systems. The present invention has been found to be particularly advantageous for characterizing color imaging systems susceptible to certain perceptual effects and for

transforming colors between color imaging systems. An appreciation of the invention is best gained through a discussion of these particular application examples.

According to one aspect of the present invention, a color characterization technique may be applied to a variety of color imaging systems to generate a characterization or profile of a color imaging system. The characterization may be used, for example, to analyze a single color imaging system or to transform the color response of one color imaging system to match the color response of another color imaging system. The color characterization technique uses a device-independent color space that includes reference vectors to compensate for perceptual effects attributable to, for example, the psychophysical response of a human viewer. These perceptual effects depend on, for example, lighting, background coloration, viewing angle, and/or other variables. By compensating for these effects, the technique accurately characterizes color imaging systems and improves the accuracy of mapping between color imaging systems.

FIG. 1 illustrates an example system 100 according to the present invention configured to characterize a color

imaging system. The system 100 includes an appropriately-programmed computer arrangement 102. The computer arrangement 102 may be implemented using any of a variety of conventional resources, for example, a personal computer and CD-ROM based software. Other computer-based designs may be used as well. For example, the computer arrangement 102 may be implemented using a microprocessor that accesses a read-only memory (ROM) into which a software application program is loaded. The software application program may be incorporated, for example, in a color-management software package, such as that provided by the Rainbow™ color proofing system, commercially available from Imation, Inc., of St. Paul, Minnesota. Alternatively, the computer arrangement 102 may be incorporated as part of an intelligent printer. In such a configuration, the software application program is loaded, for example, into a printer memory.

The computer arrangement 102 obtains color data 104 that represents colors of output samples of a color imaging system to be characterized. The color imaging system may be, for example, a color printing system, a color display system, or a color projection system. It should be

understood, however, that the color characterization technique may be applied to other types of color imaging systems according to the present invention. The color data 104 may be obtained, for example, directly from a color imaging system via a color measuring device 103 such as a colorimeter or a spectrophotometer, or by accessing a color data file stored in a color data memory 105. The dashed lines around the color measuring device 103 and the color data memory 105 of FIG. 1 indicate that either or both can provide the color data 104. For example, a colorimeter may be configured to measure color values for test patches formed on paper to characterize a color printing system.

The color measuring device 103 may comprise, for example, a color measurement system such as a Gretag™ SPM 50 color measurement device, commercially available from Gretag, Inc., of Regensdorf, Switzerland, or a densitometer such as an X-Rite color densitometer, commercially available from X-Rite, of Grandville, Michigan. Alternatively, to characterize color display or projection systems, the color measuring device optionally comprises a video camera or digital camera. The color data 104 obtained by the color measuring device may be loaded into the color data memory as

a color data file or directly loaded into a memory associated with the computer arrangement 102. The computer arrangement 102 can access the color data file to obtain previous color data 104 measured by the color measuring device. The color data memory optionally stores several color data files for a variety of different color imaging systems. The system 100 can thus be used to characterize a color imaging system selected from multiple color imaging systems having color data 104 stored in the color data memory.

The color data 104 represents, for example, CIE XYZ tristimulus values for each of a variety of color output samples generated by a color imaging system. Alternatively, the color data 104 may comprise other types of color values that can be converted to CIE XYZ tristimulus values. The color data 104 is selected to sample the range or gamut of colors that can be realized by the color imaging system under study. Selecting the color data 104 to sample the gamut broadly provides an improvement to the accuracy of the color characterization across the gamut.

The color data 104 typically includes data that the computer arrangement 102 uses in calculating a white

reference vector 108 and a black reference vector 110. This data includes, for example, color values for an imaging base, such as paper, and color values for a maximum color output of the color imaging system. The CIE XYZ tristimulus values represent the relative amounts of primary color stimuli involved in matching colors within the CIE color system. The relative X, Y, and Z values are influenced, for example, by the power distribution of the illuminant, *e.g.*, D_{50}, and the CIE standard observer function, *e.g.*, 2° or 10°. Alternatively, the color data 104 may be, for example, RGB or CMYK data.

FIG. 2 illustrates an example color characterization method 200 for characterizing a color imaging system according to the present invention. In FIG. 2, at block 202, a system, such as the color characterization system 100 of FIG. 1, obtains CIE XYZ color values. This can be accomplished, for example, either directly from color data or through conversion from another type of color data. Next, as depicted at a block 204, the system calculates a set of values known as a black reference vector. The black reference vector compensates for black point adaptation, which occurs, for example, when a

nominally black color displayed on a computer monitor appears black to the human eye despite significant stray light that imparts significantly non-zero tristimulus values to the nominally black color. The black reference vector is configurable and may be calculated using any of a variety of techniques appropriate for a particular imaging medium. For example, in certain application environments in which the black reference is near zero, a vector of zeros may be used as the black reference vector. In certain color printing systems using a cyan-magenta-yellow-black (CMYK) color space, the black reference vector may be defined using measured tristimulus values corresponding to cyan, magenta and yellow values of zero and a maximum black value. Alternatively, the black reference vector may be set using measured tristimulus values corresponding to maximum values of all four colorants or to cyan, magenta, yellow, and black values that yield maximum black ink coverage for a maximum black value. In certain other application environments using a red-green-blue (RGB) coordinate system, the black reference vector may be calculated from measured tristimulus values corresponding to red, green, and blue values of zero.

To characterize other color imaging systems, the color characterization system may calculate the black reference vector by multiplying tristimulus values of a perfect white diffuser (X_n, Y_n, Z_n) by a preselected scaling factor β. For a perfect black point, *i.e.*, a black point having zero tristimulus values, β is zero. For imperfect black points, β is non-zero. Calculating the black reference vector using a scaling factor β has been found particularly useful in transforming color values between certain color imaging systems, such as a color printing system for color printing on newsprint and the Rainbow™ color proofing system. Using measured tristimulus values to calculate the black reference vector has been found particularly useful for matching colors between a color display system for displaying colors on a color monitor and the Matchprint™ color proofing system, commercially available from Imation, Inc., of St. Paul, Minnesota.

Block 206 of FIG. 2 depicts the color characterization system calculating a white reference vector after calculating the black reference vector. It should be understood, however, that the system may alternatively calculate the white reference vector before calculating the

black reference vector. The white reference vector is a vector defined by the tristimulus values X_n, Y_n, and Z_n obtained for a white reference associated with the color imaging system. Any of a variety of white references may be used. For example, in some color imaging systems, such as those employing the CIELAB color space, the white reference vector comprises tristimulus values X_N, Y_N, and Z_N for a perfectly diffuse white reflector, *i.e.*, a medium exhibiting a maximum reflectance across the entire visible light spectrum. Using a perfectly diffuse white reflector to obtain the white reference vector yields relatively accurate results for most colors.

In certain other color imaging systems, the white reference vector is calculated from an imaging base vector defined by tristimulus values X_b, Y_b, and Z_b obtained for an imaging base associated with the particular color imaging system under study. In a color printing system, for example, the imaging base is the printing substrate on which colorants are deposited to form an image. In a color display or color projection system, the imaging base is the white point produced by the display or projection system.

This approach results in accurate reproduction of colors close to the media white.

As depicted at a block 208, after calculating the white reference vector, the color characterization system adjusts the white reference vector according to the particular color data being converted to the modified color space of the present invention. Adjusting the white reference vector (X_n, Y_n, Z_n) produces an adjusted white reference vector (X_n', Y_n', Z_n'). The adjusted white reference vector (X_n', Y_n', Z_n') is used for converting the color data to modified color data in the modified color space.

The white reference vector (X_n, Y_n, Z_n) may be adjusted using a variety of techniques, including, for example, equations and/or estimation techniques. In a color coordinate system using L^*, a^*, and b^* coordinates, the white reference vector (X_n, Y_n, Z_n) may be adjusted to generate the adjusted white reference vector (X_n', Y_n', Z_n') according to the following equations:

$$X_n' = X_b(1 - \mathrm{sat}(X, X_{bp}, X_n)) + X_n \cdot \mathrm{sat}(X, X_{bp}, X_n)$$

$$Y_n' = Y_b(1 - \mathrm{sat}(Y, Y_{bp}, Y_n)) + Y_n \cdot \mathrm{sat}(Y, Y_{bp}, Y_n)$$

$$Z_n' = Z_b(1 - \mathrm{sat}(Z, Z_{bp}, Z_n)) + Z_n \cdot \mathrm{sat}(Z, Z_{bp}, Z_n),$$

where

$$sat(X, X_{bp}, X_n) = (X - X_n) / (X_{bp} - X_n)$$

$$sat(Y, Y_{bp}, Y_n) = (Y - Y_n) / (Y_{bp} - Y_n)$$

$$sat(Z, Z_{bp}, Z_n) = (Z - Z_n) / (Z_{bp} - Z_n)$$

X_{bp}, Y_{bp}, and Z_{bp} are the tristimulus values comprising the black reference vector (X_{bp}, Y_{bp}, Z_{bp}). Alternately, a vector (X_{max}, Y_{max}, Z_{max}) comprising the tristimulus values of the most saturated values in the particular imaging system may be substituted for the black reference vector (X_{bp}, Y_{bp}, Z_{bp}). To simplify calculations, the vector (X_{max}, Y_{max}, Z_{max}) can often be set to zero because the tristimulus values approach zero in the most saturated color, *e.g.*, maximum black. Calculating saturation for each tristimulus value has been found to be more accurate in many cases than calculating a single saturation value for all three tristimulus values. For example, for certain colors, the human eye perceives significant saturation in one tristimulus value but low saturation in other tristimulus values. While the white reference vector may be adjusted using the functions described above, more complex functions can be used in certain application environments to produce improved visual matches. For example, the white reference vector can be

adjusted using higher-order polynomial functions. Alternatively, the white reference vector can be adjusted as a function of lightness and colorfulness levels.

Next, at a block 210, the tristimulus color values are converted to modified color values in a modified color space having, for example, L^*, a^*, and b^* coordinates. If the black reference vector (X_{bp}, Y_{bp}, Z_{bp}) is used in the block 208 to adjust the white reference vector, the modified color values can be calculated using, for example, the following equations:

$$L^* = 116((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - 16$$

$$a^* = 500[((X - X_{bp}) / (X_n' - X_{bp}))^{1/3} - ((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3}]$$

$$b^* = 200[((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - ((Z - Z_{bp}) / (Z_n' - Z_{bp}))^{1/3}],$$

In application environments in which the vector $(X_{max}, Y_{max}, Z_{max})$ is used to adjust the white reference vector and is set to zero, the above equations reduce to the following forms:

$$L^* = 116(Y / Y_n')^{1/3} - 16$$

$$a^* = 500[(X / X_n')^{1/3} - (Y / Y_n')^{1/3}]$$

$$b^* = 200[(Y / Y_n')^{1/3} - (Z / Z_n')^{1/3}].$$

It should be understood that other device-independent color spaces may be used for converting the tristimulus color values. Additional examples of color spaces that may be used include, but are not limited to, the HUNTLAB, ICPF LAB, and RLAB color spaces.

According to another aspect of the present invention, color transformation is effected between different color imaging systems. FIG. 3 illustrates an example method for performing this transformation. The method may be performed, for example, by the color characterization system 100 of FIG. 1. As depicted at a block 302, color data is obtained for the respective color imaging systems between which the transformation is to be performed. At a block 304, a black reference vector is calculated for each color imaging system using equations similar to those used to calculate the black reference vector in connection with the block 204 of FIG. 2. Next, at a block 306, white reference vectors are calculated or estimated for each color imaging system. The white reference vectors can be calculated in a manner similar to that used for calculating the white reference vector in connection with the block 206 of FIG. 2. As discussed in

connection with FIG. 2, this may be accomplished using an imaging base vector obtained for each color imaging system.

At a block 308, the white reference vectors for each color imaging system are adjusted according to the color data for each color imaging system. This adjustment is performed using equations similar to those used in connection with the block 208 of FIG. 2 or by estimation. The adjusted white reference vectors are then used to generate color transformation values that map color values between the color imaging systems. The color transformation values may be stored, for example, as entries in a table.

The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Those skilled in the art will readily recognize various modifications and changes that may be made to the present invention without strictly following the example embodiments and applications illustrated and described herein, and without departing from the true spirit and scope of the present invention, which is set forth in the following claims.

What is claimed is:

1. A color characterization method for characterizing a color imaging system, the method comprising:

generating first color values in a color coordinate system by using output samples of the color imaging system, the first color values representing colors of the output samples of the color imaging system; and

converting the first color values into second color values in a device-independent color coordinate system using first and second reference values, the first reference values being adjusted using the first color values.

2. A color characterization method, according to claim 1, further comprising calculating the second reference values as a function of a medium.

3. A color characterization method, according to claim 2, further comprising defining the second reference values as a vector of zeros.

4. A color characterization method, according to claim 2, further comprising defining the second reference

values using a maximum value in a black channel of the color imaging system and minimum values in at least one additional channel of the color imaging system.

5. A color characterization method, according to claim 2, further comprising defining the second reference values using maximum values in channels of the color imaging system.

6. A color characterization method, according to claim 1, further comprising calculating the first reference values using the second reference values.

7. A color characterization method, according to claim 1, further comprising generating the first color values using at least one of the following: a color measuring device, and a memory.

8. A color characterization method for characterizing a color imaging system, the method comprising:

generating first color values in a color coordinate system by using output samples of the color

imaging system, the first color values representing colors of the output samples;

converting the first color values into second color values in a device-independent color coordinate system using first and second reference values;

calculating the second reference values as a function of a medium;

calculating the first reference values using the second reference values; and

adjusting the first reference values using the first color values.

9. A color characterization method, according to claim 8, wherein the device-independent color coordinate system uses white reference tristimulus values to compensate for certain perceptual effects.

10. A color characterization method, according to claim 9, further comprising:

converting the first color values into the second color values using transformations; and

adjusting the first reference values using the first color values.

11. A color characterization method, according to claim 8, wherein the device-independent color coordinate system is an $L^*a^*b^*$ color coordinate system.

12. A color characterization method, according to claim 11, further comprising:

converting the first color values into the second color values using the equations

$$L^* = 116((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - 16$$

$$a^* = 500[((X - X_{bp}) / (X_n' - X_{bp}))^{1/3} - ((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3}]$$

$$b^* = 200[((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - ((Z - Z_{bp}) / (Z_n' - Z_{bp}))^{1/3}],$$

wherein

X, Y, and Z are tristimulus values for the first color values,

X_n', Y_n', and Z_n' are the first reference values, and

X_{bp}, Y_{bp}, and Z_{bp} are the second reference values; and

adjusting the first reference values using the tristimulus values.

13. A color characterization method, according to claim 12, further comprising adjusting the first reference values using the equations

$$X_n' = X_b(1 - sat(X, X_{bp}, X_n)) + X_n \cdot sat(X, X_{bp}, X_n)$$

$$Y_n' = Y_b(1 - sat(Y, Y_{bp}, Y_n)) + Y_n \cdot sat(Y, Y_{bp}, Y_n)$$

$$Z_n' = Z_b(1 - sat(Z, Z_{bp}, Z_n)) + Z_n \cdot sat(Z, Z_{bp}, Z_n),$$

wherein

$$sat(X, X_{bp}, X_n) = (X - X_n) / (X_{bp} - X_n)$$

$$sat(Y, Y_{bp}, Y_n) = (Y - Y_n) / (Y_{bp} - Y_n)$$

$$sat(Z, Z_{bp}, Z_n) = (Z - Z_n) / (Z_{bp} - Z_n)$$

X_n, Y_n, and Z_n are tristimulus values for a perfect white diffuser under standard viewing conditions, and

X_b, Y_b, and Z_b are tristimulus values for an imaging base associated with the color imaging system.

14. A color characterization method, according to claim 11, further comprising:

converting the first color values into the second color values using the equations

$$L^* = 116(Y / Y_n')^{1/3} - 16$$

$$a^* = 500[(X / X_n')^{1/3} - (Y / Y_n')^{1/3}]$$

$$b^* = 200[(Y / Y_n')^{1/3} - (Z / Z_n')^{1/3}],$$

wherein

X, Y, and Z are tristimulus values for the first color values, and

X_n', Y_n', and Z_n' are the first reference values; and

adjusting the first reference values using the tristimulus values.

15. A color characterization method, according to claim 14, further comprising adjusting the first reference values using the equations

$$X_n' = X_b(1 - sat(X, X_{max}, X_n)) + X_n \cdot sat(X, X_{max}, X_n)$$

$$Y_n' = Y_b(1 - sat(Y, Y_{max}, Y_n)) + Y_n \cdot sat(Y, Y_{max}, Y_n)$$

$$Z_n' = Z_b(1 - sat(Z, Z_{max}, Z_n)) + Z_n \cdot sat(Z, Z_{max}, Z_n),$$

wherein

$$sat(X, X_{max}, X_n) = (X - X_n) / (X_{max} - X_n)$$

$$sat(Y, Y_{max}, Y_n) = (Y - Y_n) / (Y_{max} - Y_n)$$

$$sat(Z, Z_{max}, Z_n) = (Z - Z_n) / (Z_{max} - Z_n)$$

X_n, Y_n, and Z_n are tristimulus values for a perfect white diffuser under standard viewing conditions,

X_{max}, Y_{max}, and Z_{max} are tristimulus values for a color having a maximum saturation associated with the color imaging system, and

X_b, Y_b, and Z_b are tristimulus values for an imaging base associated with the color imaging system.

16. A color characterization method, according to claim 8, further comprising generating the first color values using at least one of the following: a color measuring device, and a memory.

17. For use in characterizing a color imaging system, a color characterization arrangement comprising:

means for generating first color values in a color coordinate system by using output samples of the color imaging system, the first color values representing colors of the output samples; and

means for converting the first color values into second color values in a device-independent color coordinate system using first and second reference values, the first reference values being adjusted using the first color values.

18. For use in characterizing a color imaging system, a color characterization arrangement comprising:

a computer arrangement, configured and arranged to receive first color values in a color coordinate system, the first color values representing colors of output samples of the color imaging system; and

a first memory, responsive to the computer arrangement and configured and arranged to store second color values in a device-independent color coordinate system,

the computer arrangement being further configured and arranged to convert the first color values into the second color values using first and second reference values, the first reference values being adjusted using the first color values.

19. A color characterization arrangement, according to claim 18, wherein the computer arrangement is further configured and arranged to calculate the second reference values as a function of a medium.

20. A color characterization arrangement, according to claim 19, wherein the computer arrangement is

further configured and arranged to define the second reference values as a vector of zeros.

21. A color characterization arrangement, according to claim 19, wherein the computer arrangement is further configured and arranged to define the second reference values using a maximum value in a black channel of the color imaging system and minimum values in at least one additional channel of the color imaging system.

22. A color characterization arrangement, according to claim 19, wherein the computer arrangement is further configured and arranged to define the second reference values using maximum values in channels of the color imaging system.

23. A color characterization arrangement, according to claim 18, wherein the computer arrangement is further configured and arranged to calculate the first reference values using the second reference values.

24. A color characterization arrangement, according to claim 18, wherein the computer arrangement is

further configured and arranged to adjust the first reference values using the first color values.

25. A color characterization arrangement, according to claim 18, wherein the device-independent color coordinate system uses white reference tristimulus values to compensate for certain perceptual effects.

26. A color characterization arrangement, according to claim 18, wherein the computer arrangement is further configured and arranged to:

convert the first color values into the second color values using transformations; and

adjust the first reference values using the first color values.

27. A color characterization arrangement, according to claim 18, wherein the device-independent color coordinate system is an $L^*a^*b^*$ color coordinate system.

28. A color characterization arrangement, according to claim 27, wherein the computer arrangement is further configured and arranged to:

convert the first color values into the second color values using the equations

$$L^* = 116((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - 16$$

$$a^* = 500[((X - X_{bp}) / (X_n' - X_{bp}))^{1/3} - ((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3}]$$

$$b^* = 200[((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - ((Z - Z_{bp}) / (Z_n' - Z_{bp}))^{1/3}],$$

wherein

X, Y, and Z are tristimulus values for the first color values,

X_n', Y_n', and Z_n' are the first reference values, and

X_{bp}, Y_{bp}, and Z_{bp} are the second reference values; and

adjust the first reference values using the tristimulus values.

29. A color characterization arrangement, according to claim 28, wherein the computer arrangement is further configured and arranged to adjust the first reference values using the equations

$$X_n' = X_b(1 - \mathrm{sat}(X, X_{bp}, X_n)) + X_n \cdot \mathrm{sat}(X, X_{bp}, X_n)$$

$$Y_n' = Y_b(1 - sat(Y, Y_{bp}, Y_n)) + Y_n \cdot sat(Y, Y_{bp}, Y_n)$$

$$Z_n' = Z_b(1 - sat(Z, Z_{bp}, Z_n)) + Z_n \cdot sat(Z, Z_{bp}, Z_n),$$

wherein

$$sat(X, X_{bp}, X_n) = (X - X_n) / (X_{bp} - X_n)$$

$$sat(Y, Y_{bp}, Y_n) = (Y - Y_n) / (Y_{bp} - Y_n)$$

$$sat(Z, Z_{bp}, Z_n) = (Z - Z_n) / (Z_{bp} - Z_n)$$

X_n, Y_n, and Z_n are tristimulus values for a perfect white diffuser under standard viewing conditions, and

X_b, Y_b, and Z_b are tristimulus values for an imaging base associated with the color imaging system.

30. A color characterization arrangement, according to claim 27, wherein the computer arrangement is further configured and arranged to:

convert the first color values into the second color values using the equations

$$L^* = 116(Y / Y_n')^{1/3} - 16$$

$$a^* = 500[(X / X_n')^{1/3} - (Y / Y_n')^{1/3}]$$

$$b^* = 200[(Y / Y_n')^{1/3} - (Z / Z_n')^{1/3}],$$

wherein

X, Y, and Z are tristimulus values for the first color values, and

X_n', Y_n', and Z_n' are the first reference values; and

adjust the first reference values using the tristimulus values.

31. A color characterization arrangement, according to claim 30, wherein the computer arrangement is further configured and arranged to adjust the first reference values using the equations

$$X_n' = X_b(1 - sat(X,X_{max},X_n)) + X_n \cdot sat(X,X_{max},X_n)$$

$$Y_n' = Y_b(1 - sat(Y,Y_{max},Y_n)) + Y_n \cdot sat(Y,Y_{max},Y_n)$$

$$Z_n' = Z_b(1 - sat(Z,Z_{max},Z_n)) + Z_n \cdot sat(Z,Z_{max},Z_n),$$

wherein

$$sat(X,X_{max},X_n) = (X - X_n) / (X_{max} - X_n)$$

$$sat(Y,Y_{max},Y_n) = (Y - Y_n) / (Y_{max} - Y_n)$$

$$sat(Z,Z_{max},Z_n) = (Z - Z_n) / (Z_{max} - Z_n)$$

X_n, Y_n, and Z_n are tristimulus values for a perfect white diffuser under standard viewing conditions,

X_{max}, Y_{max}, and Z_{max} are tristimulus values for a color having a maximum saturation associated with the color imaging system, and

X_b, Y_b, and Z_b are tristimulus values for an imaging base associated with the color imaging system.

32. A color characterization arrangement, according to claim 18, further comprising a second memory, configured and arranged to provide the first color values to the computer arrangement.

33. A color characterization arrangement, according to claim 18, further comprising a color measuring instrument, configured and arranged to:

obtain the first color values from a sample; and

provide the first color values to the computer arrangement.

34. For use in characterizing a color imaging system, a data storage medium storing a computer-executable program configured and arranged to, when executed,

obtain first color values in a color coordinate system by using output samples of the color imaging system, the first color values representing colors of the output samples, and

convert the first color values into second color values in a device-independent color coordinate system using first and second reference values, the first reference values being adjusted using the first color values.

35. A data storage medium, according to claim 34, wherein the computer-executable program is further configured and arranged to, when executed, calculate the second reference values as a function of a medium.

36. A data storage medium, according to claim 35, wherein the computer-executable program is configured and arranged to, when executed, define the second reference values as a vector of zeros.

37. A data storage medium, according to claim 35, wherein the computer-executable program is configured and arranged to, when executed, define the second reference values using a maximum value in a black channel of the color imaging system and minimum values in at least one additional channel of the color imaging system.

38. A data storage medium, according to claim 35, wherein the computer-executable program is configured and arranged to, when executed, define the second reference values using maximum values in channels of the color imaging system.

39. A data storage medium, according to claim 34, wherein the computer-executable program is further configured and arranged to, when executed, calculate the first reference values using the second reference values.

40. A data storage medium, according to claim 34, wherein the computer-executable program is further configured and arranged to, when executed, adjust the first reference values using the first color values.

41. A data storage medium, according to claim 34, wherein the device-independent color coordinate system uses white reference tristimulus values to compensate for certain perceptual effects.

42. A data storage medium, according to claim 41, wherein the computer-executable program is further configured and arranged to, when executed,

convert the first color values into the second color values using transformations; and

adjust the first reference values using the first color values.

43. A data storage medium, according to claim 34, wherein the device-independent color coordinate system is an $L^*a^*b^*$ color coordinate system.

44. A data storage medium, according to claim 43, wherein the computer-executable program is further configured and arranged to, when executed,

convert the first color values into the second color values using the equations

$$L^* = 116((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - 16$$

$$a^* = 500[((X - X_{bp}) / (X_n' - X_{bp}))^{1/3} - ((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3}]$$

$$b^* = 200[((Y - Y_{bp}) / (Y_n' - Y_{bp}))^{1/3} - ((Z - Z_{bp}) / (Z_n' - Z_{bp}))^{1/3}],$$

wherein

X, Y, and Z are tristimulus values for the first color values,

X_n', Y_n', and Z_n' are the first reference values, and

X_{bp}, Y_{bp}, and Z_{bp} are the second reference values, and

adjust the first reference values using the tristimulus values.

45. A data storage medium, according to claim 44, wherein the computer-executable program is further configured and arranged to, when executed, adjust the first reference values using the equations

$$X_n' = X_b(1 - sat(X, X_{bp}, X_n)) + X_n \cdot sat(X, X_{bp}, X_n)$$

$$Y_n' = Y_b(1 - sat(Y, Y_{bp}, Y_n)) + Y_n \cdot sat(Y, Y_{bp}, Y_n)$$

$$Z_n' = Z_b(1 - sat(Z, Z_{bp}, Z_n)) + Z_n \cdot sat(Z, Z_{bp}, Z_n),$$

wherein

$$sat(X, X_{bp}, X_n) = (X - X_n) / (X_{bp} - X_n)$$

$$sat(Y, Y_{bp}, Y_n) = (Y - Y_n) / (Y_{bp} - Y_n)$$

$$sat(Z, Z_{bp}, Z_n) = (Z - Z_n) / (Z_{bp} - Z_n)$$

X_n, Y_n, and Z_n are tristimulus values for a perfect white diffuser under standard viewing conditions, and

X_b, Y_b, and Z_b are tristimulus values for an imaging base associated with the color imaging system.

46. A data storage medium, according to claim 43, wherein the computer-executable program is further configured and arranged to, when executed,

convert the first color values into the second color values using the equations

$$L^* = 116(Y / Y_n')^{1/3} - 16$$

$$a^* = 500[(X / X_n')^{1/3} - (Y / Y_n')^{1/3}]$$

$$b^* = 200[(Y / Y_n')^{1/3} - (Z / Z_n')^{1/3}],$$

wherein

X, Y, and Z are tristimulus values for the first color values, and

X_n', Y_n', and Z_n' are the first reference values, and

adjust the first reference values using the tristimulus values.

47. A data storage medium, according to claim 46, wherein the computer-executable program is further configured and arranged to, when executed, adjust the first reference values using the equations

$$X_n' = X_b(1 - sat(X, X_{max}, X_n)) + X_n \cdot sat(X, X_{max}, X_n)$$

$$Y_n' = Y_b(1 - sat(Y, Y_{max}, Y_n)) + Y_n \cdot sat(Y, Y_{max}, Y_n)$$

$$Z_n' = Z_b(1 - sat(Z, Z_{max}, Z_n)) + Z_n \cdot sat(Z, Z_{max}, Z_n),$$

wherein

$$sat(X, X_{max}, X_n) = (X - X_n) / (X_{max} - X_n)$$

$$sat(Y, Y_{max}, Y_n) = (Y - Y_n) / (Y_{max} - Y_n)$$

$$sat(Z, Z_{max}, Z_n) = (Z - Z_n) / (Z_{max} - Z_n)$$

X_n, Y_n, and Z_n are tristimulus values for a perfect white diffuser under standard viewing conditions,

X_{max}, Y_{max}, and Z_{max} are tristimulus values for a color having a maximum saturation associated with the color imaging system, and

X_b, Y_b, and Z_b are tristimulus values for an imaging base associated with the color imaging system.

48. A data storage medium, according to claim 34, wherein the computer-executable program is further

configured and arranged to, when executed, store the second color values in a memory.

49. A color transformation method for performing a color transformation between first and second color imaging systems, the color transformation method comprising:

generating first and second color values by using output samples of the first and second color imaging systems, the first and second color values respectively representing colors of the output samples of the first and second color imaging systems;

converting the first and second color values respectively into third and fourth color values using a device-independent color coordinate system;

calculating first reference values from a medium and second reference values from the first reference values;

adjusting the second reference values using the first and second color values; and

generating color transformation values using the third and fourth color values.

50. A color characterization method, according to claim 49, wherein the device-independent color coordinate

system uses white reference tristimulus values to compensate for certain perceptual effects.

51. A color characterization method, according to claim 50, further comprising:

converting the first color values into the second color values using transformations; and

adjusting the first reference values using the first color values.

52. A color transformation method, according to claim 49, wherein the color coordinate system is an $L^*a^*b^*$ color coordinate system.

53. A color transformation method, according to claim 52, further comprising:

converting the first color values into the third color values using the equations

$$L^* = 116((Y_1 - Y_{bp1}) / (Y_{n1}' - Y_{bp1}))^{1/3} - 16$$

$$a^* = 500[((X_1 - X_{bp1}) / (X_{n1}' - X_{bp1}))^{1/3} - ((Y_1 - Y_{bp1}) / (Y_{n1}' - Y_{bp1}))^{1/3}]$$

$$b^* = 200[((Y_1 - Y_{bp1}) / (Y_{n1}' - Y_{bp1}))^{1/3} - ((Z_1 - Z_{bp1}) / (Z_{n1}' - Z_{bp1}))^{1/3}],$$

wherein

X_1, Y_1, and Z_1 are tristimulus values for the first color values,

X_{bp1}, Y_{bp1}, and Z_{bp1} are black tristimulus values for the first color imaging system, and

X_{n1}', Y_{n1}', and Z_{n1}' are white reference tristimulus values for the first color imaging system;

converting the second color values into the fourth color values using the equations

$$L^* = 116((Y_2 - Y_{bp2}) / (Y_{n2}' - Y_{bp2}))^{1/3} - 16$$

$$a^* = 500[((X_2 - X_{bp2}) / (X_{n2}' - X_{bp2}))^{1/3} - ((Y_2 - Y_{bp2}) / (Y_{n2}' - Y_{bp2}))^{1/3}]$$

$$b^* = 200[((Y_2 - Y_{bp2}) / (Y_{n2}' - Y_{bp2}))^{1/3} - ((Z_2 - Z_{bp2}) / (Z_{n2}' - Z_{bp2}))^{1/3}],$$

wherein

X_2, Y_2, and Z_2 are tristimulus values for the second color values,

X_{bp2}, Y_{bp2}, and Z_{bp2} are black tristimulus values for the second color imaging system, and

X_{n2}', Y_{n2}', and Z_{n2}' are white tristimulus values for the second color imaging system; and

adjusting the second reference values using the black tristimulus values for the first and second color imaging systems.

54. A color transformation method, according to claim 53, further comprising:

adjusting the white reference tristimulus values for the first color imaging system using the equations

$$X_{n1}' = X_{b1}(1 - sat(X_1, X_{bp1}, X_{n1})) + X_{n1} \cdot sat(X_1, X_{bp1}, X_{n1})$$

$$Y_{n1}' = Y_{b1}(1 - sat(Y_1, Y_{bp1}, Y_{n1})) + Y_{n1} \cdot sat(Y_1, Y_{bp1}, Y_{n1})$$

$$Z_{n1}' = Z_{b1}(1 - sat(Z_1, Z_{bp1}, Z_{n1})) + Z_{n1} \cdot sat(Z_1, Z_{bp1}, Z_{n1}),$$

wherein

$$sat(X_1, X_{bp}, X_n) = (X_1 - X_{n1}) / (X_{bp1} - X_{n1})$$

$$sat(Y_1, Y_{bp}, Y_n) = (Y_1 - Y_{n1}) / (Y_{bp1} - Y_{n1})$$

$$sat(Z_1, Z_{bp1}, Z_{n1}) = (Z_1 - Z_{n1}) / (Z_{bp1} - Z_{n1})$$

X_{n1}, Y_{n1}, and Z_{n1} are tristimulus values for a perfect white diffuser associated with the first color imaging system under standard viewing conditions, and

X_{b1}, Y_{b1}, and Z_{b1} are tristimulus values for an imaging base associated with the first color imaging system; and

adjusting the white reference tristimulus values for the second color imaging system using the equations

$$X_{n2}' = X_{b2}(1 - sat(X_2, X_{bp2}, X_{n2})) + X_{n2} \cdot sat(X_2, X_{bp2}, X_{n2})$$

$$Y_{n2}' = Y_{b2}(1 - sat(Y_2, Y_{bp2}, Y_{n2})) + Y_{n2} \cdot sat(Y_2, Y_{bp2}, Y_{n2})$$

$$Z_{n2}' = Z_{b2}(1 - sat(Z_2, Z_{bp2}, Z_{n2})) + Z_{n2} \cdot sat(Z_2, Z_{bp2}, Z_{n2}),$$

wherein

$$sat(X_2, X_{bp}, X_n) = (X_2 - X_{n2}) / (X_{bp2} - X_{n2})$$

$$sat(Y_2, Y_{bp}, Y_n) = (Y_2 - Y_{n2}) / (Y_{bp2} - Y_{n2})$$

$$sat(Z_2, Z_{bp2}, Z_{n2}) = (Z_2 - Z_{n2}) / (Z_{bp2} - Z_{n2})$$

X_{n2}, Y_{n2}, and Z_{n2} are tristimulus values for a perfect white diffuser associated with the second color imaging system under standard viewing conditions, and

X_{b2}, Y_{b2}, and Z_{b2} are tristimulus values for an imaging base associated with the second color imaging system.

55. A color characterization method, according to claim 52, further comprising:

converting the first color values into the third color values using the equations

$$L^* = 116(Y_1 / Y_{n1}')^{1/3} - 16$$

$$a^* = 500[(X_1 / X_{n1}')^{1/3} - (Y_1 / Y_{n1}')^{1/3}]$$

$$b^* = 200[(Y_1 / Y_{n1}')^{1/3} - (Z_1 / Z_{n1}')^{1/3}],$$

wherein

X_1, Y_1, and Z_1 are tristimulus values for the first color values, and

X_{n1}', Y_{n1}', and Z_{n1}' are white reference tristimulus values for the first color imaging system;

converting the second color values into the fourth color values using the equations

$$L^* = 116(Y_2 / Y_{n2}')^{1/3} - 16$$

$$a^* = 500[(X_2 / X_{n2}')^{1/3} - (Y_2 / Y_{n2}')^{1/3}]$$

$$b^* = 200[(Y_2 / Y_{n2}')^{1/3} - (Z_2 / Z_{n2}')^{1/3}],$$

wherein

X_2, Y_2, and Z_2 are tristimulus values for the second color values, and

X_{n2}', Y_{n2}', and Z_{n2}' are white reference tristimulus values for the second color imaging system; and

adjusting the first reference values using the black tristimulus values for the first and second color imaging systems.

56. A color transformation method, according to claim 55, further comprising:

adjusting the white reference tristimulus values for the first color imaging system using the equations

$$X_{n1}' = X_{b1}(1 - \mathrm{sat}(X_1, X_{max1}, X_{n1})) + X_{n1} \cdot \mathrm{sat}(X_1, X_{max1}, X_{n1})$$

$$Y_{n1}' = Y_{b1}(1 - \mathrm{sat}(Y_1, Y_{max1}, Y_{n1})) + Y_{n1} \cdot \mathrm{sat}(Y_1, Y_{max1}, Y_{n1})$$

$$Z_{n1}' = Z_{b1}(1 - \mathrm{sat}(Z_1, Z_{max1}, Z_{n1})) + Z_{n1} \cdot \mathrm{sat}(Z_1, Z_{max1}, Z_{n1}),$$

wherein

$$\mathrm{sat}(X_1, X_{max1}, X_{n1}) = (X_1 - X_{n1}) / (X_{max1} - X_{n1})$$

$$\mathrm{sat}(Y_1, Y_{max1}, Y_{n1}) = (Y_1 - Y_{n1}) / (Y_{max1} - Y_{n1})$$

$$\mathrm{sat}(Z_1, Z_{max1}, Z_{n1}) = (Z_1 - Z_{n1}) / (Z_{max1} - Z_{n1})$$

X_{n1}, Y_{n1}, and Z_{n1} are tristimulus values for a perfect white diffuser associated with the first color imaging system under standard viewing conditions,

X_{max1}, Y_{max1}, and Z_{max1} are tristimulus values for a color having a maximum saturation associated with the first color imaging system, and

X_{b1}, Y_{b1}, and Z_{b1} are tristimulus values for an imaging base associated with the first color imaging system; and

adjusting the white reference tristimulus values for the second color imaging system using the equations

$$X_{n2}' = X_{b2}(1 - sat(X_2, X_{max2}, X_{n2})) + X_{n2} \cdot sat(X_2, X_{max2}, X_{n2})$$

$$Y_{n2}' = Y_{b2}(1 - sat(Y_2, Y_{max2}, Y_{n2})) + Y_{n2} \cdot sat(Y_2, Y_{max2}, Y_{n2})$$

$$Z_{n2}' = Z_{b2}(1 - sat(Z_2, Z_{max2}, Z_{n2})) + Z_{n2} \cdot sat(Z_2, Z_{max2}, Z_{n2}),$$

wherein

$$sat(X_2, X_{max2}, X_{n2}) = (X_2 - X_{n2}) / (X_{max2} - X_{n2})$$

$$sat(Y_2, Y_{max2}, Y_{n2}) = (Y_2 - Y_{n2}) / (Y_{max2} - Y_{n2})$$

$$sat(Z_2, Z_{max2}, Z_{n2}) = (Z_2 - Z_{n2}) / (Z_{max2} - Z_{n2})$$

X_{n2}, Y_{n2}, and Z_{n2} are tristimulus values for a perfect white diffuser associated with the second color imaging system under standard viewing conditions,

X_{max2}, Y_{max2}, and Z_{max2} are tristimulus values for a color having a maximum saturation associated with the second color imaging system, and

X_{b2}, Y_{b2}, and Z_{b2} are tristimulus values for an imaging base associated with the second color imaging system.

57. For use in performing a color transformation between first and second color imaging systems, a color transformation arrangement comprising:

means for generating first color values by using output samples of the first color imaging system, the first color values representing colors of the output samples of the first color imaging system;

means for generating second color values by using output samples of the second color imaging system, the second color values representing colors of the output samples of the second color imaging system;

means for converting the first color values into third color values using a color coordinate system;

means for converting the second color values into fourth color values using the color coordinate system;

means for calculating first reference values from a medium and second reference values from the first reference values;

means for adjusting the second reference values using the first and second color values; and

means for generating color transformation values using the third and fourth color values.

Abstract

Characterizing a color imaging system involves generating color values representing colors of output samples of the color imaging system. The color values are converted into a device-independent color coordinate system using an adjustable white reference vector and a black reference vector. The white reference vector is calculated using the black reference vector. Color values can be transformed between color imaging systems using the device-independent color coordinate system.

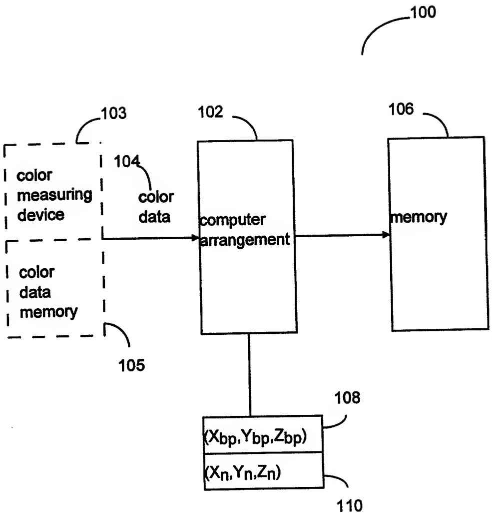
100
103
102
106
color measuring device
104
color data
computer arrangement
memory
color data memory
105
108
(X_{bp}, Y_{bp}, Z_{bp})
(X_n, Y_n, Z_n)
110

FIG. 1

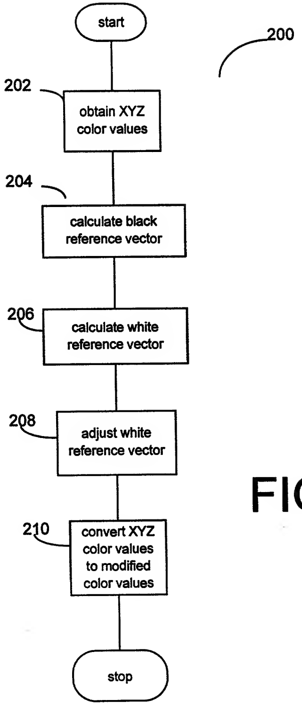
start
200
202
obtain XYZ color values
204
calculate black reference vector
206
calculate white reference vector
208
adjust white reference vector
210
convert XYZ color values to modified color values
stop

FIG. 2

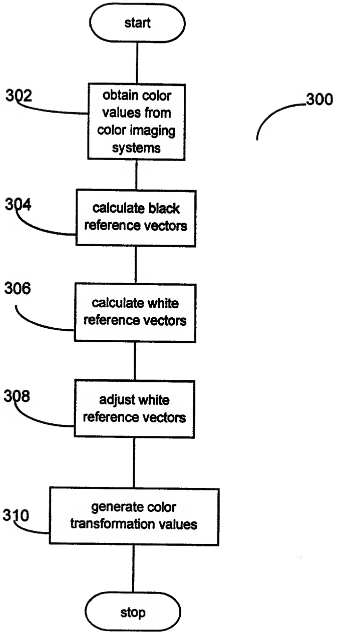
start
302
obtain color values from color imaging systems
300
304
calculate black reference vectors
306
calculate white reference vectors
308
adjust white reference vectors
310
generate color transformation values
stop

FIG. 3

MERCHANT, GOULD, SMITH, EDELL, WELTER & SCHMIDT

United States Patent Application

DECLARATION

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: CHARACTERIZATION OF COLOR IMAGING SYSTEMS.

The specification of which:

a. ☐ is attached hereto
b. ☒ is entitled CHARACTERIZATION OF COLOR IMAGING SYSTEMS, having an attorney docket number of 4362.31US01.
c. ☐ was filed on as application serial no. and was amended on (if applicable) (in the case of a PCT-filed application) described and claimed in international no. filed and as amended on (if any), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

a. ☒ no such applications have been filed.
b. ☐ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**
ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (Day, Month, Year)

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Minneapolis, MN 55402-4131

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Signature of Inventor 202:			**Date:**	

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.